Available online at www.sciencedirect.com
ScienceDirect
Omega 35 (2007) 494–504
omega
The International Journal of Management Science
www.elsevier.com/locate/omega

Supplier selection with multiple criteria in volume discount environments

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Received 18 December 2004; accepted 12 September 2005
Available online 25 October 2005

Abstract

Supplier selection is a multi-criteria decision making problem which includes both qualitative and quantitative factors. In order to select the best suppliers it is necessary to make a trade-off between these tangible and intangible factors some of which may conflict. When business volume discounts exist, this problem becomes more complicated as, in these circumstances, buyer should decide about two problems: which suppliers are the best and how much should be purchased from each selected supplier. In this article an integrated approach of analytical hierarchy process improved by rough sets theory and multi-objective mixed integer programming is proposed to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers in the case of multiple sourcing, multiple products, with multiple criteria and with supplier's capacity constraints. In this context, suppliers offer price discounts on total business volume, not on the quantity or variety of products purchased from them. A solution methodology is presented to solve the multi-objective model, and the model is illustrated using two numerical examples.

Keywords: Supplier selection; AHP; Volume discount; Rough sets; Multi-criteria; Multi-objective

1. Introduction

Supplier selection decisions are an important component of production and logistics management for many firms. Such decisions entail the selection of individual suppliers to employ, and the determination of order quantities to be placed with the selected suppliers. Selecting right suppliers significantly reduces the material purchasing cost and improves corporate competitiveness,which is why many experts believe that the supplier selection is the most important activity of a purchasing department [1,2].

Many factors affect a supplier's performance. Dickson [3] identified 23 criteria that have been considered by purchasing managers in various supplier selection problems. More recently, a review of supplier selection criteria and methods by Weber et al. [4] found that 47 of the 76 articles reviewed addressed more than one criterion. Hence supplier selection problem (SSP) is a multiple criteria problem and it is necessary to make a trade-off between conflicting tangible and intangible factors to find the best suppliers. SSP is complicated by the fact that various criteria must be considered in the decision making process. SSP is further complicated by the fact that individual suppliers may have

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doi:10.1016/j.omega.2005.09.002

different performance characteristics for different criteria. For example, the supplier who can supply an item for the lowest per unit price may not have the best quality or service performance among the competing suppliers. Supplier selection is therefore an inherent multi-objective decision that seeks to minimize procurement cost, maximize quality and service performance concurrently.

Often complicating the SSP for the buyer is the presence of price discounts, offered by supplier, that depend on the total value of sales volume, not on the quantity or variety of products purchased over a given period of time. In traditional quantity discount pricing schedules, price breaks are a function of the order quantity which existed for each product, irrespective of the total purchasing volume over a given period of time. With the advent of just-in-time (JIT) purchasing, the strategy that calls for ordering smaller lot-size is more practical and feasible. So suppliers are finding it more meaningful to give discounts based on the total value of multi-product orders (i.e. total business volume) placed by a given buyer.

The remainder of this paper is organized as follows. The Section 2 cites the relevant literature to SSP. The improved analytic hierarchy process (AHP) by rough sets theory is introduced in Section 3. Formulation of the multi-objective mathematical model is presented in Section 4. Section 5 describes the experimental design and solution methodology to multi-objective optimization. Finally, concluding remarks are provided in Section 6.

2. Literature review

Basically there are two kinds of SSP:

(1) *Single sourcing*. Constraints are not considered in the supplier selection process. In other words, all suppliers can satisfy the buyer's requirements of demand, quality, delivery, etc. The buyer only needs to make one decision, which supplier is the best.

(2) *Multiple sourcing*. Some limitations such as supplier's capacity, quality, delivery are considered in the supplier selection process. In other words, no one supplier can satisfy the buyer's total requirements and the buyer needs to purchase some part of demand from one supplier and the other part from another supplier to compensate for the shortage of capacity or low quality of the first supplier. In these circumstances buyers need to make two decisions: which suppliers are the best, and how much should be purchased from each selected supplier?

The vast majority of the decision models applied to the supplier selection are linear weighting models and mathematical programming models.

2.1. Linear weighting models

In linear weighting models weights are given to the criteria, the biggest weight indicating the highest importance. Ratings on the criteria are multiplied by their weights and summed in order to obtain a single figure for each supplier. The supplier with the highest overall rating can then be selected. Over the past 15–20 years a wide variety of slightly different linear weighting models have been proposed for supplier selection.

Narasimhan [5], Nydick and Hill [6], and Barbarosoglu and Yazgac [7] proposed the use of the AHP to deal with SSP. In short, AHP circumvents the difficulty of having to provide point estimates for criteria weights as well as performance scores in the basic linear weighting models. Instead, using AHP the buyer is only required to give verbal, qualitative statements regarding the relative importance of one criterion versus another criterion and similarly regarding the relative preference for one supplier versus another on a criterion. This approach is more accurate than the other scoring methods.

Another group of authors has suggested various statistical techniques to deal with imprecision while using linear weighting models. Min [8] and Petroni and Braglia [9] applied the so-called "indifference trade-off" method and principal component analysis, respectively, for the same purpose. Although the techniques differ, they have in common that the buyer does not need to provide precise numerical criteria weights directly. However, the use of these statistical methods will clearly not be straightforward for most users and make the process quite cumbersome.

Finally, a number of authors suggest to use fuzzy sets theory to model uncertainty and imprecision in supplier choice situations. Fuzzy sets theory offers a mathematically precise way of modeling vague preferences, for example, when it comes to setting weights of performance scores on criteria. An example presented by Morlacchi [10] has developed a model that combines the use of fuzzy set with AHP and implemented it to evaluate several suppliers in the engineering and machine sectors. In addition, Li et al. [11] and Holt [12] discussed the application of fuzzy sets theory in supplier selection.

2.2. Mathematical programming models

Given an appropriate decision setting, mathematical programming allows the decision maker to formulate